The modulus (h) of the velocity of rotation (v_r) is : $h = \frac{v_r^2}{g} = \left(\frac{t_1}{t_0}\right)^2 r$.

Substituting the values of v_r, g, t_1, t_0, we find $h = \frac{1525.78^2}{32.088} = \left(\frac{5074}{86164}\right)^2 r$ $= 13.741$ miles $= \frac{1}{288.4} r$.

This gives 3949.084 miles for the polar radius, which is $\frac{1}{2}$ mile less than Bessel's estimate, and about $\frac{3}{10}$ of a mile less than Clarke's estimate from the results of the British Ordinance Survey. It accords very closely, however, as we might reasonably have anticipated, with the ellipticity $\left(\frac{1}{288.5}\right)$ as deduced from pendulum experiments. *

Relations of Chemical Affinity to Luminous and Cosmical Energies. By Pliny Earle Chase, LL.D.

(*Read before the American Philosophical Society, April* 16, 1880.)

All the principles which I have applied successfully to the discovery of harmonic relations of cosmical mass and density, should be applicable also to the discovery of similar relations of molecular mass and density, and to a consequent extension of our knowledge of chemical physics. The application can be made most properly by chemical experts, but some indications of the methods to be pursued may be acceptable, even though they come from one who makes no claim to any special chemical experience.

In 1833, Sir John Herschel published his remarkable attribution to the energy of the Sun's rays, "of almost every motion which takes place on the surface of the Earth. By its heat are produced all winds, and those disturbances in the electric equilibrium of the atmosphere which give rise to the phenomena of lightning, and probably also to those of terrestrial magnetism and the aurora."†

In 1856, Kohlrausch found that the ratio between the electrostatic and the electromagnetic units was apparently, and perhaps exactly, equivalent to the velocity of light‡ (v_λ).

In 1863, I found that the reaction of gravity to the elasticity and *vis viva* of atmospheric rotation, furnished a simple method for approximately estimating the Sun's distance by means of barometric fluctuations,§ and began a series of studies of cosmical and molecular harmonies which are dependent and consequent upon general kinetic laws.

In the year following,‖ I announced "the discovery of certain new relations between the solar and lunar diurnal variations of magnetic force

* Enc. Brit., 9th edition, vii, 601.
† Outlines of Astronomy, § 399.
‡ Pogg. Ann.
§ Proc. Am. Phil. Soc., ix, 287.
‖ Ib. ix, 425.

and of barometric pressure," showing a numerical equivalence between tidal attractions and magnetic disturbances. In 1873, in his "Electricity and Magnetism" (vol. ii, p. 127), Maxwell suggested the tidal hypothesis, apparently without knowing that I had already adopted it and adduced evidence to sustain it.

In 1875, I showed that analogues of Ohm's law are operative in General Physics, Electricity, Chemistry, and Cosmogony, and that Maxwell's deductions, when combined with my theoretical assumptions, led to the ratio : Earth's mass : Sun's mass : : 1 : 327710.*

Prof. Robert B. Warder has lately called my attention to the fact that the co-efficients of elasticity seem to lend some confirmation to Mendelejeff's and Meyer's hypotheses of periodical chemical functions, and thus I have been induced to look for further chemical illustrations of the universal influence of luminous undulations.

In the general equation of absolute measure, $u = F(l, m, t)$, u, l, m and t represent, respectively, units of velocity, length, mass and time.

In Mechanical measure, the dimensions of the unit of force (k), which, in unit of time, communicates unit of velocity to unit mass, are $l\,m\,t^{-2}$.

In Electrostatic measure, the unit of quantity (ε), which repels an equal quantity at unit distance with unit force, is $l^{\frac{3}{2}}\,m^{\frac{1}{2}}\,t^{-1}$.

In Magnetic measure, the unit of quantity (μ), or strength of unit pole, is also, $l^{\frac{3}{2}}\,m^{\frac{1}{2}}\,t^{-1}$.

Kohlrausch's equation, $u = l\,t^{-1} = v_{\lambda}$, has been subsequently investigated by Weber, Thomson, Maxwell, and Perry and Ayrton, each successive examination increasing the probability that the electric dimensional value of $l\,t^{-1}$ is precisely equivalent to the velocity of light.

If we adopt for our mechanical unit, the maximum energy of gravitation in the solar system, we get the following equation :

$$g = l\,m\,t^{-2} = m\,u\,t^{-1} \ldots\ldots A$$

The units of Electrostatic and Magnetic measure, both give the equation :

$$l^{\frac{3}{2}}\,m^{\frac{1}{2}}\,t^{-1} = mu.\,m^{-\frac{1}{2}}\,l^{\frac{1}{2}} \ldots\ldots B$$

From these dimensional equations the value of the unit of absolute momentum (mu), is readily deduced. If we multiply (A) by the identical equation $t = t$, and (B) by the equation of orbital velocity ($v = m^{\frac{1}{2}}\,l^{-\frac{1}{2}}$†), we get

$$gt = mu = mv_{\lambda} \ldots\ldots C$$

$$\varepsilon v = mu = mv_{\lambda} \ldots\ldots D$$

$$\mu v = mu = mv_{\lambda} \ldots\ldots E$$

Under the guidance of foregoing investigations I find the following interpretation for this equivalence.

The centre of gravity of the solar system has a locus of secular range

* Ib. xiv, 607—9.

† Substituting r for l, the equations $g = \frac{m}{r^2}$ and $v = \sqrt{gr}$, give $v = m^{\frac{1}{2}} r^{-\frac{1}{2}}$.

relatively to Sun's centre, nearly, and perhaps exactly, equivalent to Sun's diameter.*

The two controlling bodies of the system, Sun and Jupiter, are of nearly equal density, and their centre of gravity, which is also the centre of greatest relative stability, has a locus of relative secular range about equivalent to $\frac{1}{8}$ of Sun's diameter, its secular perihelion, or locus of primitive rupture, being at Sun's surface. The gravitating motions beyond the limits of the system, and the æthereal motions at all points, should be referred to the centre of greatest stability; but as we approach that centre the gravitating tendencies towards Sun's centre become more and more preponderating. The gravitating motions are greatest at Sun's surface, where solar gravity (g_0), is 27.83 times as great as terrestrial superficial equatorial gravity (g_3). In solar rotation, the particles are subject to continual æthereal and gravitating forces, referable to the centre of stability and to Sun's centre, respectively.

Projectile velocities at Earth's surface, may be represented either by gt or by $\sqrt{gh}$, t being $\frac{1}{2}$ the time of flight and h being twice the virtual rise or fall. Reasoning from analogy we may, therefore, presume that t, in equations A, B and C, represents $\frac{1}{2}$ solar rotation, l represents the height of a homogeneous æthereal atmosphere, at Sun's surface, which would have a wave-velocity equivalent to that of light, and m represents a *minimum mobile*, or constituent molecule. These conditions are all satisfied by the values, solar rotation = 25.486 dys; $t = 12.743$ dys. $= 1100985$ sec.; $v_\lambda = 688.815 \sqrt{gr}$; l = modulus of light $= (688.815)^2\, r = 2206.5$ Earth's semi-axis major = 73.64 Neptune's semi-axis major.

An æthereal sphere, rotating with velocity $\sqrt{gr}$ at Sun's surface, would have v_λ at $688.815\, r$. If $mu = v_\lambda$ in both cases, the densities would be inversely as the distances. In a condensing or expanding nebula, the nucleal radius varies as the $\frac{3}{4}$ power of the atmospheric or Laplace-limiting radius, and in an elastic atmosphere the density varies geometrically, with an exponent inverse to the arithmetical variation of the distances or to the square of arithmetical variation or *vis viva* of rotation. Sun's mean distance is 23395.4 terrestrial radii, and $23395.4\, r \div (\frac{3}{4})^2$ of $688.815 = 60.38\, r$, which is the value of Moon's semi-axis major, as found by the limiting time-ratio of terrestrial rotation to satellite revolution.†

The tendency of all movements in elastic media, either to complete or to harmonic synchronism, should introduce some simple relations of chemical *vis viva* to *vis viva* of terrestrial motion. The law of Dulong and Petit, with Clausius's modifying substitution of the square of the molecular velocity for the specific heat, may be expressed by the equation $\frac{wv^2}{t} = C$, in which w represents the atomic weight, v the molecular velocity, according to the kinetic theory of gases, and t the absolute temperature. Since

* From *a priori* considerations I am inclined to think that the accordance is exact.

† Proc. Am. Phil. Soc., xix, 9.

the terrestrial movements are either independent of the absolute temperature, or standing in unknown relations to it, the simplest evidence of equivalent *vis viva* should be sought at some specific temperature, and in the most typical and most widely diffused gases. We have already seen that the universal typical liquid, H_2O, furnishes data for a ready determination of Joule's equivalent, at the mean temperature of solidification ($2°C = 35°.6$ F); let us examine the constituent typical gases (H,O) at the same temperature.

According to Clausius,* the mean velocities of the molecules are:

	At 0°C.	At 2°C.
Oxygen,	461 $m = 1514$ ft.	464.4 $m = 1525.1$ ft.
Hydrogen,	1844 $m = 6050$ ft.	1857.5 $m = 6094.3$ ft.

Earth's equatorial velocity of rotation (1525.78 ft.) accords with the molecular velocity of oxygen; its velocity of revolution is 16 times the velocity of hydrogen. If w_n represents the atomic weight of any perfect gas n, the velocity at 2°C may be found by the equation:

$$v_n = \frac{4v_r}{\sqrt{w_n}} = \frac{1}{16}\sqrt{\frac{gr}{w_n}}.$$

The mean molecular velocity of oxygen and hydrogen (3048.7), is to Earth's orbital velocity, as the square of the time of fall to the centre from any distance d, is to the square of the time of orbital revolution at d.

The following comparison with the results of Cornu's and Michelson's experimental determinations of the velocity of light, and with my own estimation of Sun's mass and distance from the explosive energy of H_2O,† will show the closeness of agreement between the chemical and other physical approximations.

	Sun's Distance.	Velocity of Light.
Chase, H_2O	92,639,500 miles,	186,090 miles = 299,470 km.
Michelson,	92,748,000 "	186,300 " = 299,820 "
Chase, H	92,756,000 "	186,320 " = 299,850 "
" HO	92,803,000 "	186,420 " = 300,000 "
" O	92,849,000 "	186,510 " = 300,150 "
Cornu,	92,803,000 "	186,420 " = 300,000 "

It may be interesting, in this connection, to give two additional illustrations of the tendency to harmonic wave lengths in elementary spectra, of which I have already presented many evidences.‡

If we take $n = \frac{1}{285}$, we find that Vogel's wave-lengths,§ of the ultra-violet lines in the spectrum of hydrogen, are strictly harmonic, as will be

* Phil. Mag., 1857, xiv, 124.

† Proc. Am. Phil. Soc., 1872, xii, 394.

‡ Proc. Am. Phil. Soc., xvii, 109–12, 295–301; xviii, 224–6.

§ Photographic News, February 20, 1880.

seen by the following table. Column T contains theoretical harmonic wave-lengths; V contains Vogel's measurements:

		T	V
α	$3968.4 \div 1$	$= 3968.4$	3968
β	$3968.4 \div (1 + 6\,n)$	$= 3886.6$	3887
γ	$3968.4 \div (1 + 10\,n)$	$= 3833.9$	3834
δ	$3968.4 \div (1 + 13\,n)$	$= 3795.3$	3795
ε	$3968.4 \div (1 + 15\,n)$	$= 3770.$	3770

The divisors ($\beta = 1 + 6\,n$; $\gamma = 1 + 10\,n$: etc.) give the following proportions:

$\beta - \alpha : \varepsilon - \alpha$: : mean *v.v.* of rotation : Equatorial *v.v.* of rotation.

$\varepsilon - \gamma : \varepsilon - \beta$: : wave *v.v.* : molecular *v.v.*

$\varepsilon - \delta : \varepsilon - \gamma : : \beta - \alpha : \varepsilon - \alpha$.

If we take $n = \frac{1}{12}$, Paalzow's oxygen lines * (P) are also nearly harmonic (T_1).

	T_1	T_2	P
$602 \div 1$	$= 602.$	602.	602.
$602 \div (1 + n)$	$= 555.7$	558.2	558.2
$602 \div (1 + 2\,n)$	$= 516.$	519.2	519.
$602 \div (1 + 3\,n)$	$= 481.6$	481.1	481.
$602 \div (1 + 4\,n)$	$= 451.5$	452.3	453.

The numbers in column T_2 are also harmonic, if we take $n = \frac{1}{385}$.

Stated Meeting, May 7, 1880.

Present, 15 members.

President, Mr. Fraley, in the Chair.

Letters accepting membership were received from Mr. Ellis Yarnall, dated 105 S. Front Street, Philadelphia, April 21, 1880; Dr. Austin Flint, Jr., New York City, 14 West 33d Street, April 21; Mr. Joseph C. Fraley, 1833 Pine Street, Philadelphia, April 22; Mr. Horace Howard Furness, 222 West Washington Square, Philadelphia, April 24; Rev. George Dana Boardman, 3815 Walnut Street, West Philadelphia, April 26; Mr. J. Vaughan Merrick, Philadelphia, April 27; Mr. Wm. B. Rogers, Jr., 1000 Walnut Street, Philadelphia, April 27, and Mr. C. P. Patterson,

* Monatsber. der K. Akad. zu Berlin, Sept., Oct., 1878.